STATION CARRIER EQUIPMENT

CONTENTS

1. GENERAL

1.1 This section is intended to provide REA borrowers, consulting engineers and other interested parties with technical information on station carrier equipment. It describes the basic concepts of station carrier, the major operating characteristics of presently available equipment and is intended to provide a basic general knowledge of station carrier equipment. A companion TE&CM Section 911, "Station Carrier Application," is the "working" section that discusses the engineering and application of station carrier

systems. Additional information on carrier system fundamentals and subscriber carrier can be found in REA TE&CM Sections 901, "Fundamentals of Carrier Telephone," and 910, "Subscriber Carrier Equipment."

1.2 Station carrier was developed in 1965 from broad objectives[1] based on a 1964 subscriber loop survey.[2] These objectives were designed to encourage new developments and improvements rather than establish many rigid requirements that may hinder development of improved methods of serving subscribers. The requirements for this equipment are covered in REA Specification PE-62, "Station Carrier Equipment."

1.3 This section is separated into several subsections for reference purposes. Paragraph 2 is a general introductory section. The characteristics of the multichannel and single channel types of equipment are covered in paragraphs 3 and 4. A discussion on crosstalk and noise is covered in paragraph 5 and system coordination is in paragraph 6. These two paragraphs were considered important enough to be discussed under separate headings.

2. GENERAL CHARACTERISTICS

2.1 Station carrier systems have made use of both the good and bad experience of the previous 15 years of subscriber carrier use. This type of subscriber carrier equipment has several improved features that set it apart from previous subscriber carrier. Station carrier systems can be easily installed without alignment or periodic adjustments. Solid state devices are very reliable today; operating experience showed that maintenance costs on station carrier averaged less than $15 per channel per year.[3]

2.2 Station carrier generally falls into two categories--single channel and multichannel. The differences in the two types are basically imposed by economics. The multichannel types were especially designed to meet the needs of rural telephone systems and are generally used at distances greater than 18 kilofeet from the central office. The single channel systems are very simple in design and application and compliment the multichannel systems since they are generally applied to cable less than 18 kilofeet in length.

2.3 Station carrier is "movable plant." Obsolescence is reduced because the equipment can be removed from one location and installed at another location with very little engineering consideration and no alignment.

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1 "Objectives for a One Party Subscriber Carrier System," A. H. Flores, J. M. Flanigan, IEEE June 1965, University of Colorado, Boulder, Colorado

2 "Subscriber Loop Plant and Rural Telephone Systems," W. J. Lally, R. E. Hitt, IEEE Transactions on Communication Technology, Vol. Com-14, No. 1, February 1966

3 "The Evolution of Station Carrier and Recent Operating Experience," A. H. Flores, T. L. Moore, IEEE Transactions on Communication Technology, Vol. COM-19, No. 2, April 1971

2.4 Experience has shown that carrier systems operate best in shielded cables. Jacketed RDW is not far different from cable in terms of loss but when the carrier equipment and RDW strand are connected to the power multigrounded neutral, excessive failures can result. Open wire and RDW should be limited to voice drop use. The problems of short open wire and RDW drops from the subscriber terminal to the residence should be much less than that of long physical circuits using open wire and RDW.

2.5 Electronic equipment has a high rate of infant mortality (early failures). "Burn in" and "shake" tests at the factory have helped reduce field failures. The telephone company can further weed out equipment damaged in shipment. The equipment should be placed in operating condition (power applied) in the central office at least overnight and dialing, talking, listening and ringing tests made <u>before</u> it is taken out and placed into service. By doing this installation problems are reduced. This procedure is discussed in REA Standard PC-4, "Acceptance Tests and Measurements of Telephone Plant." Once the equipment is in and working for a few days, there are usually few problems.

3. MULTICHANNEL STATION CARRIER

3.1 <u>Application Characteristics</u>: The multichannel types of station carrier were designed especially for the rural telephone systems. To date, all types are capable of operating with at least three repeaters, distribute subscriber terminals one at a time where needed, are powered from the central office and are relatively easy to install and maintain. Some of the systems offer options to extend the distance capability, powering options, signaling options (including special services) and grouping of subscriber terminals in cabinets. There are generally no adjustments or strapping options to be made in the field on these systems. Because of the low carrier frequencies involved, there has been no difficulty in providing systems that are not tailored for a specific outside plant facility. This has simplified the engineering of these systems greatly. The early systems all provided for multiparty ringing. Some of the newer systems provide only for one party ringing, often resulting in substantial cost reductions. Some types of multiparty station carrier offer two party ANI capability.

3.11 The multichannel station carrier systems operate in the same basic manner as earlier subscriber carrier systems. The multichannel station carrier systems are primarily designed to operate over cable facilities; this helps reduce the complexity in design and application. Figure 1 shows a sample layout of a six channel system. Depending on the exact type, each subscriber terminal can be individually installed at separate locations and each can provide 1, 2 or 4 party service. The subscriber terminals can be located at any point between the central office and the termination at the end of the line. The repeaters are located at nominal 35 dB (at 112 kHz) intervals. The physical wire pairs between

the office and subscriber terminals are generally reserved for carrier frequencies and to provide power for the repeaters and the subscriber terminals. It is generally not economical to use the carrier pair to serve subscribers on a physical basis. For details on station carrier application, refer to TE&CM 911.

3.2 Voice Frequency Transmission: The voice frequency net loss is adjusted at the factory; it is usually set at 2 to 4 dB loss. The subscriber terminal is generally located near the house or houses served by the carrier. The drop between the carrier and telephone set is usually short and affects the overall net loss only slightly. All multichannel types of station carrier presently available use compandors (or other noise reducing techniques). The noise generally measures in the order of 0 to 10 dBrnc at the telephone set. If the noise exceeds 20 dBrnc, it most often can be traced to a cause other than carrier equipment. Sources of noise and noise reduction techniques are discussed in paragraph 5.

3.3 Carrier Frequency and Level Coordination: There are many types of carrier equipment in service today using a variety of frequency allocations. This has resulted in dedicating a cable for a particular type of carrier. From this experience there was early agreement that a frequency standard was necessary. All of the station carrier systems meeting the frequency and level requirements of PE-62 are expected to coordinate under the same cable sheath.

3.31 All of the multichannel station carrier systems currently use automatic level coordination. The central office terminal transmits carrier (all channels) at all times at a fixed level (somewhere between 0 dBm and -10 dBm). These signals are monitored at each repeater and the gain of the repeater in both directions is automatically set. Each subscriber terminal monitors the received carrier signal for its channel only. It then transmits a carrier signal inverse in level to the received signal. If the subscriber terminal is near to the central office terminal or just beyond a repeater, the received signal will be strong; thus, the subscriber transmit level will be low. If the subscriber terminal receives a weak carrier signal, it will transmit a high level signal somewhere between 0 dBm and -15 dBm depending on the frequency and make of equipment. This is demonstrated in Figure 2. All signals are received at approximately the same levels at the central office without regard to where the subscriber terminals are located. For more information on the coordination of carrier systems, refer to paragraph 6.

3.4 Powering: With minor exceptions, all present repeaters and subscriber terminals are powered from the central office battery. Power is fed from the central office terminal over the carrier wire pair either on a loop or simplex-to-ground basis. Most of the subscriber

terminals contain rechargeable batteries. Commerical power is sometimes used to power large concentrated groups of subscriber terminals and, looking to the near future, extended length systems may need intermediate power inserted at a convenient point in the main cable route.

3.5 Dialing: Dialing information or pulse signaling (off hook and on hook) is transmitted from the subscriber to central office terminal by turning the subscriber transmitted carrier on and off at the dialing rate. The detected carrier at the central office provides a closed contact (seizure) for the COE (Figure 3). Station carrier provides excellent dialing capability.

3.6 Ringing: The multichannel station carrier equipments handle ringing information in several ways. The earliest type used a voice frequency (inband) tone in series with the ringing generator at the central office. When ringing voltage at 16 to 66 hertz was applied to a line, an inband tone was also applied (Figure 4). The central office carrier terminal ignored the high voltage from the ringing generator but modulated the carrier with the inband tone. The tone was filtered and detected in the subscriber's residence to trigger a ringing generator and rings bells in the conventional manner. Frequency selective ringing is accomplished by assigning a different frequency tone filter for each party.

3.61 Most of the systems modulate the carrier with the ringing voltage (at reduced level). This signal is demodulated at the subscriber terminal and provides ringing voltage in the following ways: Most types simply amplify (or something similar such as an overdriven amplifier) this voltage to provide selective ringing (Figure 5). This is probably the most expensive method used. For one party service the detected ringing at the subscriber terminal may trigger a 20 hertz generator to ring a straight line ringer. (The frequency may not be stable enough for frequency selective ringers.) These one party systems require less power and are less expensive. Most of these systems use batteries in the subscriber terminals (or in the detector at the residence). The batteries would not be needed except for the large amount of power required to ring bells. One type does not use batteries. The designers assumed that no more than two of the six channels would ever ring at once and provided the power directly over the line. This concept is working well at this time. The use of tone ringers in the telephone sets could completely eliminate the use of batteries with station carrier. These tone devices can be made far more efficient than conventional ringing devices. Since batteries now represent a significant portion of maintenance costs of station carrier, it would be to the advantage of telephone companies to help promote tone ringing as a standard. This is expected to be the standard in the future along with one party service; such tone ringing systems could further reduce station carrier costs.

3.7 Packaging: There are several packaging arrangements used with station carrier equipment. Two ideas prevail with outside mounted subscriber terminals and repeaters. One is to use completely sealed units; the other

is to use a housing that can be opened for part (card) substitution. Depending on the specific type, the equipment may be pole mounted, strand mounted or direct buried. Most units contain wire terminals for connection to wire and cable pairs. The types that can be direct buried must have a stub cable and be watertight.

3.8 Electrical Protection: Capacitor discharge surge tests have proven very useful in investigating protection problems of trunk carrier repeaters. These same testing techniques were required for station carrier. Equipment meeting these electrical protection requirements generally have few failures that are believed to be from lightning. Equipment experiencing excessive failures due to lightning has also failed to pass surge test requirements. Most of the present station carrier equipment use small gas tubes for protection. These tubes have provided excellent protection from lightning but will not carry the long duration power fault currents from the electric system. These type failures have occurred in areas of high ground resistance where the electronic equipment is connected to the power multigrounded neutral.

4. SINGLE CHANNEL STATION CARRIER

4.1 Application Characteristics: The single channel station carrier system is an add-on type; that is, a carrier channel added on to an existing physical circuit. Present single channel carriers are designed to be applied to shielded cable facilities. Because of the limits of the nonloaded physical circuit, the design and application of this carrier is generally limited to 18 kilofeet. All single channel systems to date provide one party service, are mounted in the subscriber's residence and are not repeatered. It generally would not be economical to repeater this type of carrier. Powering the subscriber terminal has been accomplished either by a battery that is trickle charged from the physical circuit or by ac in the residence. Simplicity and economy are the keywords for this type of equipment.

4.11 Figure 6 shows some uses of the single channel station carrier systems. These single channel systems can provide both temporary and permanent relief where cables are filled and more circuits are needed. One of the attractive uses of this equipment is to provide a second telephone to a residence, especially for teenagers. The "system" consists of a carrier channel (both the central office terminal and subscriber terminal) and a field mounted low pass filter. The low pass filter at the central office is either a part of the channel or a part of the shelf in which the channel is mounted.

4.12 In general, both the physical and carrier derived circuit should be one party and within 18 kilofeet. Extending the range of the physical and carrier can be accomplished by filters and other special devices such as bypassed loading coils. If multiparty service is required for the physical, some precautions are needed.

(a) If the subscriber terminal contains a battery that is charged from the physical circuit, the physical should not be used for multiparty service.

(b) The simple and inexpensive low-pass filters generally used with station carrier can degrade the physical if (1) there is a long tap beyond the filter and (2) two or more filters are used to isolate the taps. See Figure 7 for examples of this.

4.2 Voice Frequency Transmission: The voice frequency net loss is adjusted at the factory; it is usually set at 2 to 4 dB loss. All of the single channel types to date are mounted in the residence and the inside wiring is limited to about 25 ohms between the channel voice drop terminals and the telephone set. Thus, the total loss between the central office and the telephone set is essentially that of the carrier system. The idle channel noise is generally in the order of 10 to 15 dBrnc at the telephone set.

4.3 Carrier Level Coordination: Some single channel types of station carrier provide automatic carrier level coordination and one uses frequency modulation to improve crosstalk noise. For the most part, these systems are simple and inexpensive and do not contain carrier level coordination in the subscriber to central office direction and do not utilize compandors. Even without these features, good cable fills with these one channel types are expected in telephone systems of REA borrowers. On occasion the telephone company may have to resort to the more costly single channel or multichannel types if noise or crosstalk complaints occur.

4.4 Dialing: Dialing information is transmitted by turning the subscriber transmitted carrier on and off as described in paragraph 3.5.

4.5 Ringing: The single channel station carriers provide only one party ringing; thus, the method of providing ringing is generally simple and inexpensive. Most of these systems simply use the ringing supply at the central office to turn the central office transmitted carrier on and off at the ringing cycle rate. (The ringing frequency is ignored.) If the ringing cycle is on two seconds and off four seconds, the central office carrier would be transmitting two seconds, off four seconds, etc. The presence of carrier is detected at the subscriber terminal to trigger the ringing generator. The ringing signal at the subscriber terminal (Figure 8) generally consists of a (nominal) 20 hertz signal at about 70 volts to ring straight line ringers (not frequency selective). One type uses the detected signal to provide a switched or warbled tone ringing signal from a small speaker (Figure 9).

4.51 One type of single channel station carrier modulates the central office terminal with the ringing voltage (at reduced level). This detected ringing signal is amplified at the subscriber terminal to reproduce the exact ringing frequency used at the central office (Figure 5).

4.6 AC Power: Some subscriber terminals are powered by ac in the subscriber's residence. These types generally use a small energy limiting transformer and use inside telephone wiring for power wiring.

5. EFFECTS OF CROSSTALK AND OTHER INTERFERING SIGNALS

5.1 Introduction: This is a brief discussion of the effects of interfering signals entering the speech path of a telephone circuit. The total effect of all interfering signals entering the speech path simultaneously can be referred to as noise and can be measured with a noise measuring set for quantitative (dB) comparison. There are several ways to measure noise and for any given method even the dB comparison is not a complete comparison. Certain types of interference are more annoying than others; for this discussion only one of these will be singled out; intelligible crosstalk. Also discussed are some noise reduction techniques.

5.2 Sources of Noise: When monitoring a carrier channel, a low level hum or random noise may be heard. Some of the sources of this noise may include power supplies, transistors, diodes, resistors, central office equipment, radio transmitters and other carrier channels in the same system or from parallel systems. Depending on the type of noise and level of the noise, it may or may not be objectionable. Many people are conditioned to hearing background noise and without it may think the circuit is out of order. (Dial tone and ringback tone can be reassuring.) These effects of the noise are discussed in three categories:

(a) Idle Channel Noise
(b) Disturbed Channel Noise
(c) Signal to Noise Ratio

5.21 Idle Channel Noise: This generally refers to the noise measured on one channel when all other channels are idle. The other channels may have signaling tones modulating the carrier (inband or out-of-band signaling). In fact, idle channel noise is frequently measured with the other channels carrying their normal telephone traffic (conversation or signaling tones). To the person using the carrier channel, idle channel noise refers to the noise heard when the parties at both ends of the circuit are listening (neither end talking). It is during this listening period that the noise must remain very low to avoid customer complaints.

5.22 Disturbed Channel Noise: Disturbed channel noise is the same as idle channel noise (both parties listening) except that disturbing signals are applied to other channels, either one at a time or to many channels simultaneously. Disturbed channel noise can be random in nature if it comes from many sources and is mixed together. Inverted speech results from a sideband of one channel demodulating with the carrier frequency of another channel that is 4 kHz different. When this happens,

a 1000 Hz tone becomes 3000 Hz, 2500 Hz becomes 1500 Hz, etc. Adjacent channel interference (one form of intrasystem crosstalk) where second and third order sidebands demodulate with carrier frequencies 8 or 12 kHz away produces similar results. For this discussion this form of crosstalk will be treated as random noise. The worst type of interference results from the disturbing sidebands demodulating with its own carrier frequency or when the measured channel is the same frequency as the disturbing channel. If this interfering noise is of sufficient level, intelligible crosstalk will result; that is, speech from other channels can be heard and understood.

5.23 Signal-to-Noise Ratio: While listening on a circuit, the noise must be relatively quiet to be satisfactory. While talking on a circuit, the noise can increase considerably before it becomes disturbing. The controlling factor becomes signal to noise and not noise alone. A signal-to-noise ratio of 25 to 30 dB is probably sufficient for a high quality voice telephone circuit. On this basis, if the talker level arrives at the listener at -20 dBm, the noise during the talking condition could be 40 to 45 dBrnc (-45 to -50 dBm). This is sometimes a difficult type of noise to measure and is usually considered a laboratory measurement. For the present a talking test should be sufficient to determine if the signal-to-noise ratio is suitable. In practice a talking test is the final determining factor anyway. The main reason for discussing signal-to-noise ratio is to assist in the explanation of noise reduction techniques.

5.3 Noise Reduction Techniques: There are at least three methods to reduce the noise and crosstalk of carrier systems that enters the channel at carrier frequencies. These methods are compandors, voice-operated switches or frequency modulation. Compandors are in widespread use today in wireline carrier systems. Figure 10 shows how a compandor reduces noise. It is the expandor that reduces the noise in the idle (listening) condition. In the talking condition the compressor improves the signal-to-noise ratio. With everything referenced to 0 dB (not necessarily dBm), the expandor can improve the idle channel noise by 30 dB (all compandors are not alike). In the talking condition a -20 dB talker is compressed to -10 dB (for this example only) and results in a 10 dB signal to noise improvement. A high level noise at -45 dB would result in 35 dB signal to noise ratio. A voice-operated switch functions somewhat like an expandor. In the idle condition the speech path to the listener is attenuated, thus reducing the noise. In the talking condition the speech path is normal, neither adding to nor reducing the noise. In the twilight zone between the idle and talking condition there is a threshold area of abrupt change in the speech path. The setting of this threshold is critical. If the threshold is set too high, the weaker speech signals will not get through. If it is set too low, it may be operated by noise and not be effective. Both the compandor and voice-operated switch operate at a syllabic rate, on speech syllables. The

compandor must track (compress and expand equally) over the range of syllabic speech levels that can exist in subscriber loops. This ranges from the very high levels of bull talkers to the weak levels sometimes encountered from low level talkers on long distance circuits. Below the low speech levels, there are noise advantages in expanding more than compressing. In a sense, such a device might act as a compandor in the normal voice range and as a voice-operated switch at very low levels. Frequency modulation noise advantage is more complex and depends on modulation deviation. FM advantage is very effective in reducing noise but is beyond the scope of this discussion.

5.4 Summary: In summary, the noise heard (or measured) when parties at both ends are listening is of first importance. Compandors or noise suppression devices help because they in effect block out any intelligible or other types of interference. When one party is talking and the other listening, the (speech) signal-to-noise ratio becomes the criteria.

6. COORDINATION OF CARRIER SYSTEMS

6.1 Coordination Considerations: The degree that one type of carrier system will coexist with another depends on several things. Some of the more important are mutual coupling, carrier frequencies and levels, and noise reduction techniques. There must be coupling for one system to interfere with another. Properly designed carrier systems minimize coupling through voice frequency paths and common power supplies. The coupling referred to here is cable and wire crosstalk.

6.11 If there is little or no coupling between the cable or wire pairs of different systems, system coordination is not a consideration. For example, if one type of carrier is placed in one binder group of a 400 pair cable and another type in another binder group, the probability of crosstalk is small. The following paragraphs on system coordination relate to small cables where crosstalk coupling can be significant. Cable crosstalk is poorer at higher frequencies (about 6 dB poorer per octave). The low frequencies used for station carrier take advantage of better cable crosstalk performance at low frequencies.

6.12 REA issued objectives for cable crosstalk in about 1960. All cables supplied to REA borrowers since January 1964 have had to meet certain crosstalk requirements. The recommendations in this section are based on cables meeting present crosstalk requirements. This should cover the great majority of all cable in service at this time in systems of REA borrowers. There is a good probability that cables manufactured before 1960 have sufficient crosstalk isolation also. There are margins for error in our recommendations but, if older cable (especially paper insulated) is suspect, crosstalk measurements should be made.

6.13 Coordination problems of different carrier systems are minimized by using the same frequencies and levels. For example, there are three

type carrier systems (N1, N2 and N3) but the carrier frequencies and levels are the same. (In fact, the same "N" carrier repeatered line could be used for either system.) Where the carrier frequency of one system falls into the sideband region of another system, crosstalk probability increases. The frequency standard specified in PE-62 minimizes carrier system coordination problems between different types of station carrier systems.

6.14 Noise reduction techniques such as compandors can reduce the effects of foreign signal interference by 15 to 30 dB over systems not using compandors.

6.2 Crosstalk Tests and Results: Laboratory measurements, field measurements and calculations relating to crosstalk with station carrier have been made by REA, manufacturers and others. The most significant REA field test on coordination of station carrier was made in 1969. Station carrier of three manufacturers was applied to small size cables and tests yielded no evidence of crosstalk among systems. All systems had compandors or other noise reducing devices. There have been limited tests on the use of T1 types of carrier and station carrier in the same cable. These results look promising. There is little possibility of the station carrier interfering with the T1. Also, the power contained in the three volt pulse of the T1 is small at the low frequencies of station carrier (below 120 kHz) The station carrier may need compandors to coordinate with T1 in small cables. Hopefully, station carrier will coordinate with other digital carrier systems also.

6.3 System Coordination Recommendations: Measurements and calculations show that multichannel station carrier can be applied to cables on a large scale basis. This excellent coordination has been made possible by good compandored carrier systems, good cables meeting REA crosstalk requirements and the low frequencies used in station carrier. General recommendations for the multichannel types are as follows:

(a) Station carrier systems of different manufacturers and different frequency allocations can coordinate in the same cable (all using the PE-62 frequency standard).

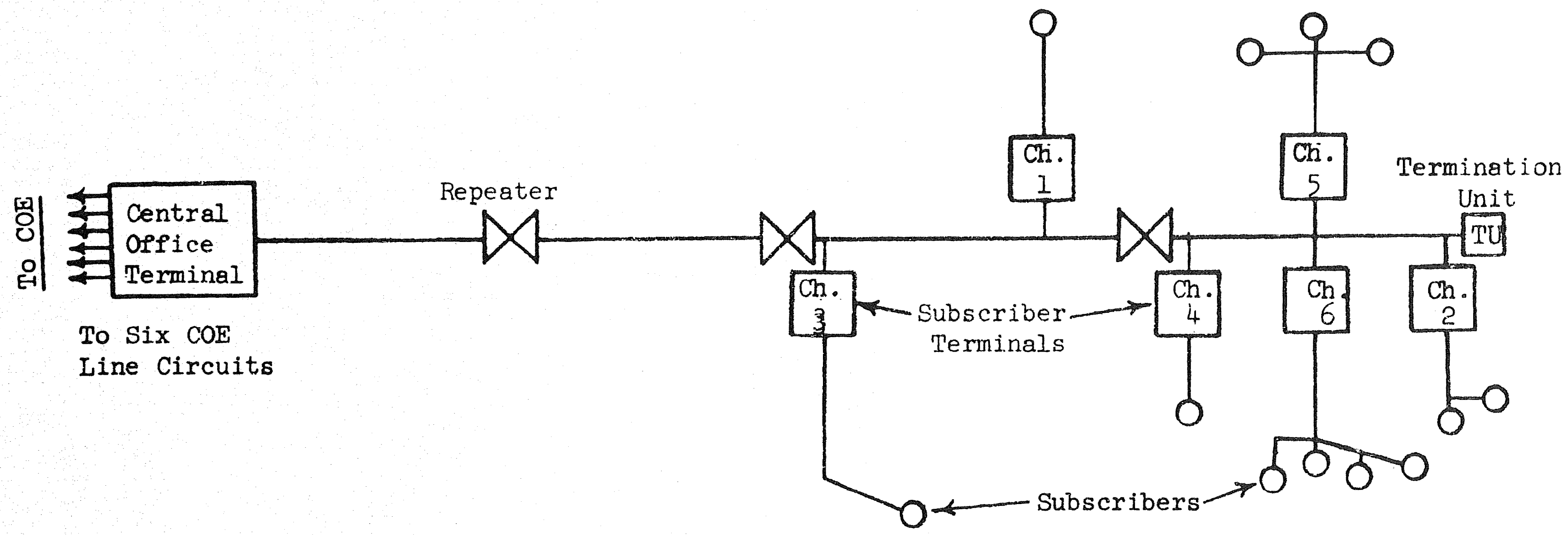
(b) Station carrier systems can be applied to 100 percent of the cable pairs (even on small cables) meeting REA cable crosstalk requirements.

(c) Station carrier systems can coordinate with T1 type carrier systems (see paragraph 6.32).

Although coordination tests between station carrier and T1 types have been limited, preliminary results show the following. Station carrier and T1 carrier can operate on adjacent pairs where crosstalk would not be suitable for either adjacent station carrier systems or adjacent T1 carrier systems. With this in mind, pairs could be selected to separate directions of transmission for the T1 carrier and all other pairs used for station carrier.

6.31 Most of the single channel station carrier systems are simple and inexpensive. They generally do not contain noise reduction techniques or automatic subscriber transmit level control. For the most part, the subscriber terminals are used close in (between 10 and 18 kilofeet) and are used on larger size cables. As a general recommendation, the single channel types can be used on a large percentage of cable pairs. On occasion, the more expensive types of station carrier may have to be used to replace the single channel types.

6.32 The T1 carrier referred to in this section is the conventional T1 repeatered line used with terminals producing a random bipolar pulse bit stream. Developments are under way for using the T1 repeatered line with terminals using encoding processes that are different from the current D1 and D2 encoding process. Such systems may or may not coordinate with station carrier in the same cable.



Subscriber Terminals Can Individually Be Located At Any Point Along The Cable Route

FIGURE 1

APPLICATION OF MULTICHANNEL STATION CARRIER

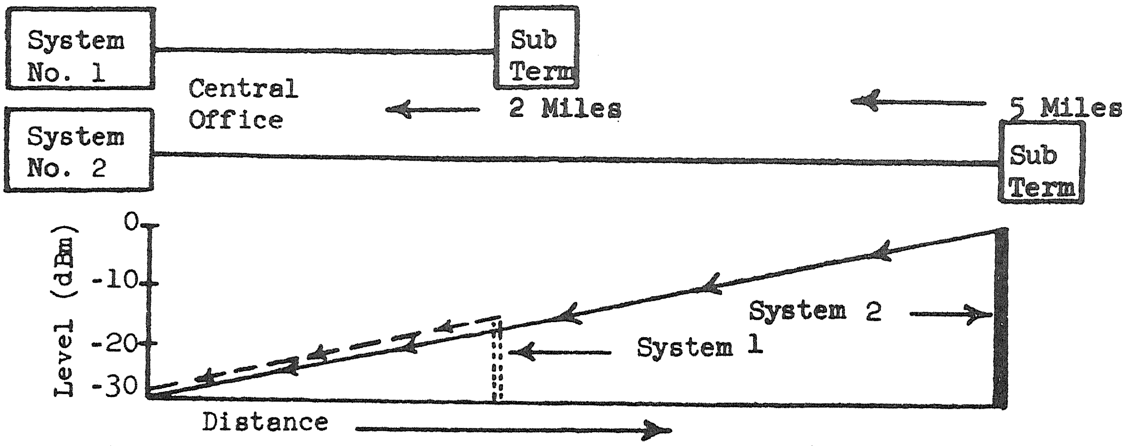


FIGURE 2

SUBSCRIBER TRANSMITTED CARRIER LEVEL VS. DISTANCE

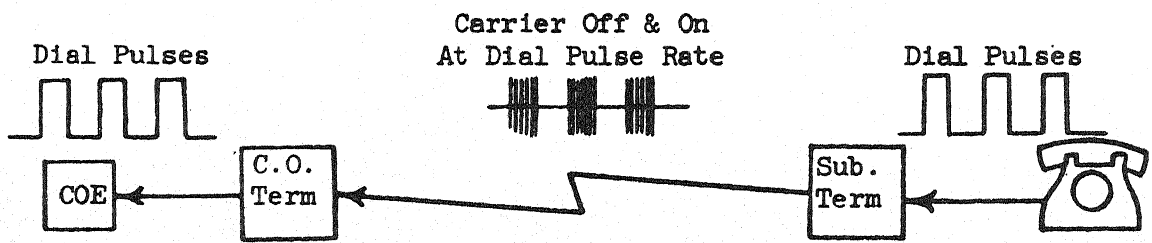


FIGURE 3

DIALING

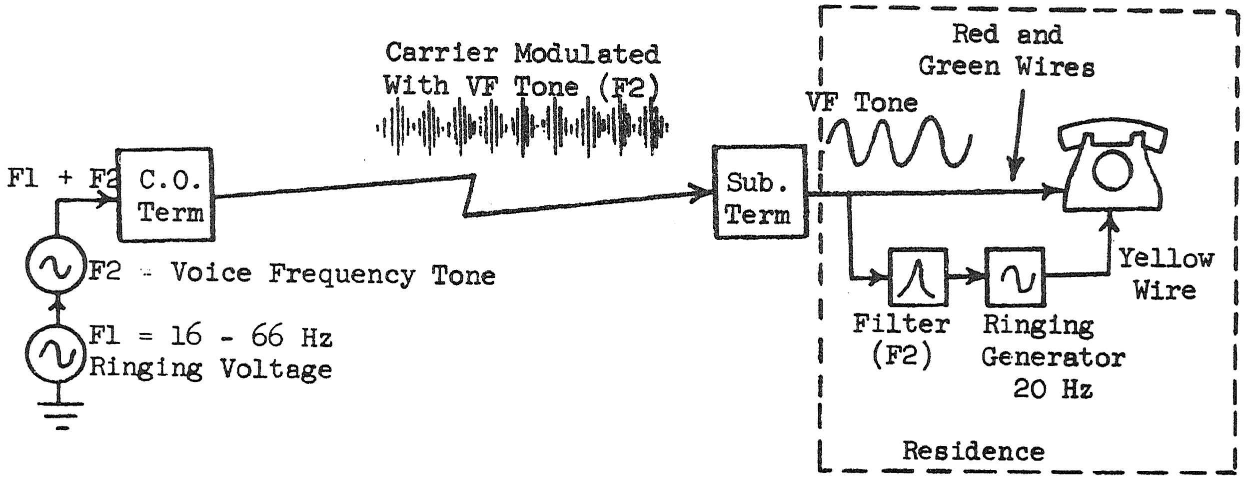


FIGURE 4

RINGING

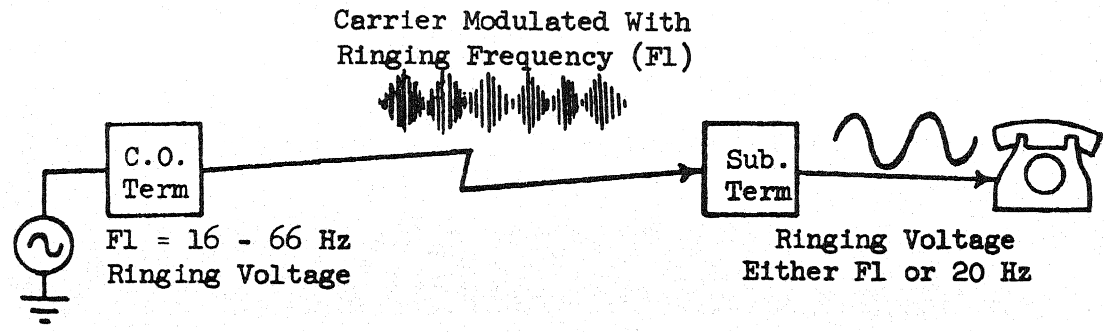
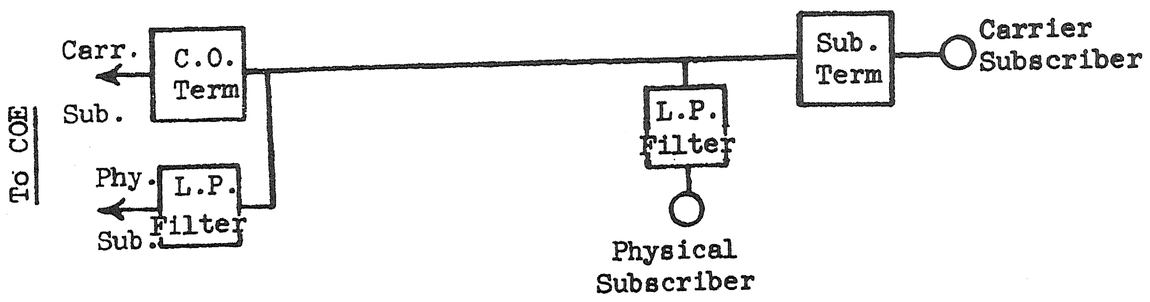
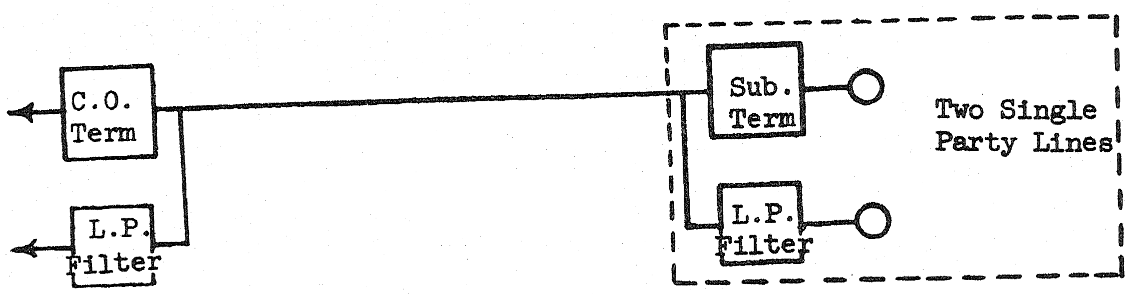


FIGURE 5

RINGING



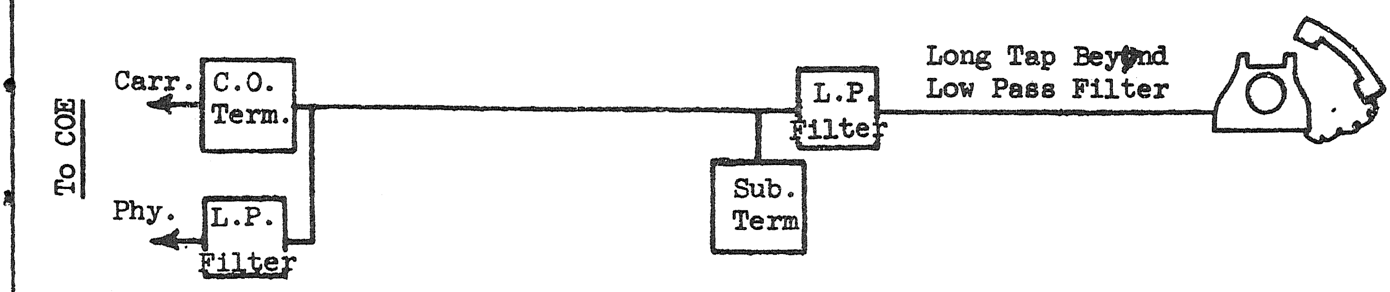
A. TWO PRIVATE LINES ON ONE CABLE PAIR



B. SECOND TELEPHONE IN SAME RESIDENCE

FIGURE 6

APPLICATION OF SINGLE CHANNEL STATION CARRIER



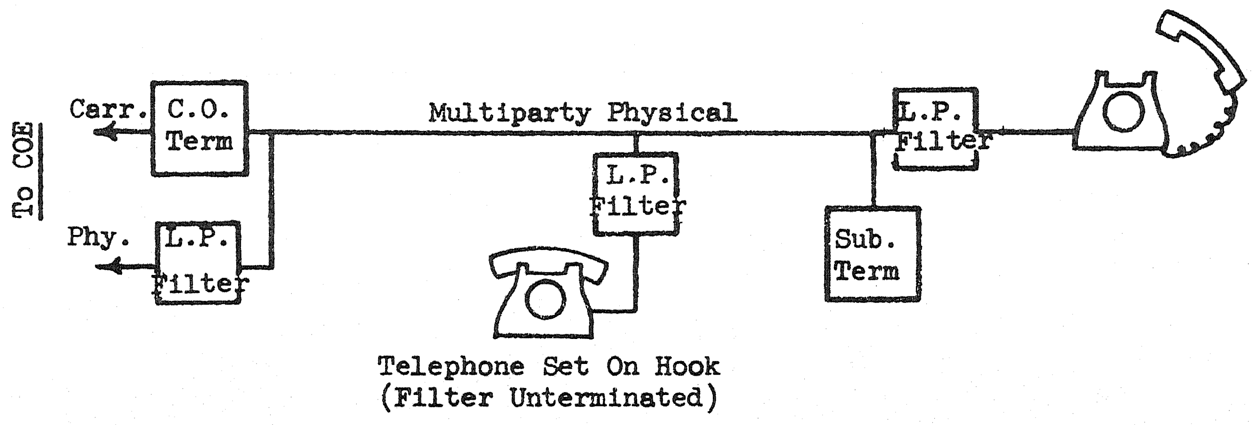


FIGURE 7

PHYSICAL CIRCUIT DEGRADATION CAN OCCUR
IN SOME APPLICATIONS USING SIMPLE
AND INEXPENSIVE LOW PASS FILTERS

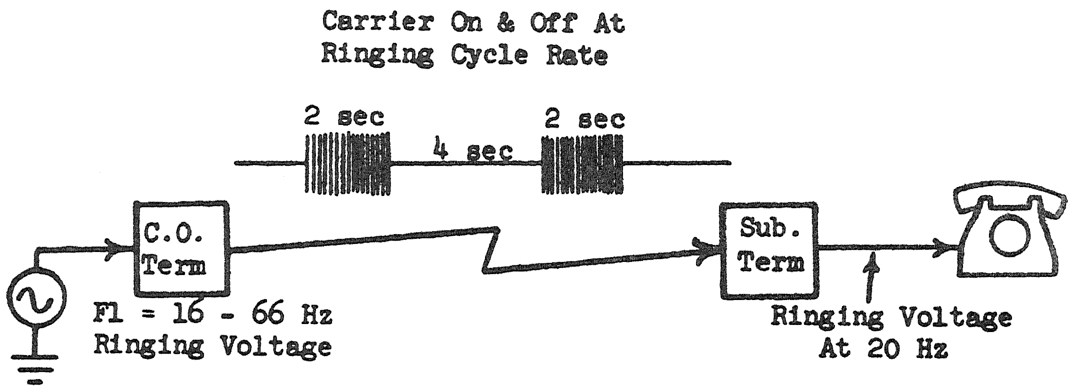


FIGURE 8

RINGING

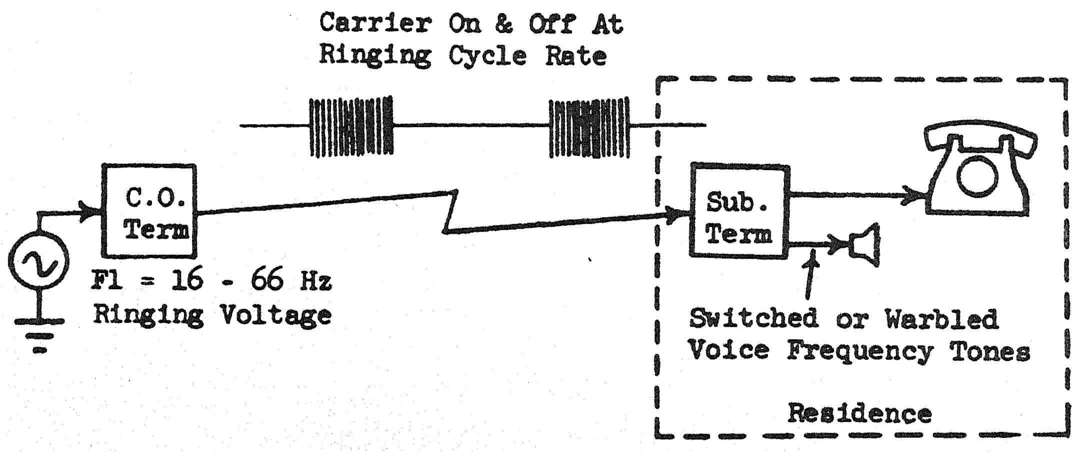
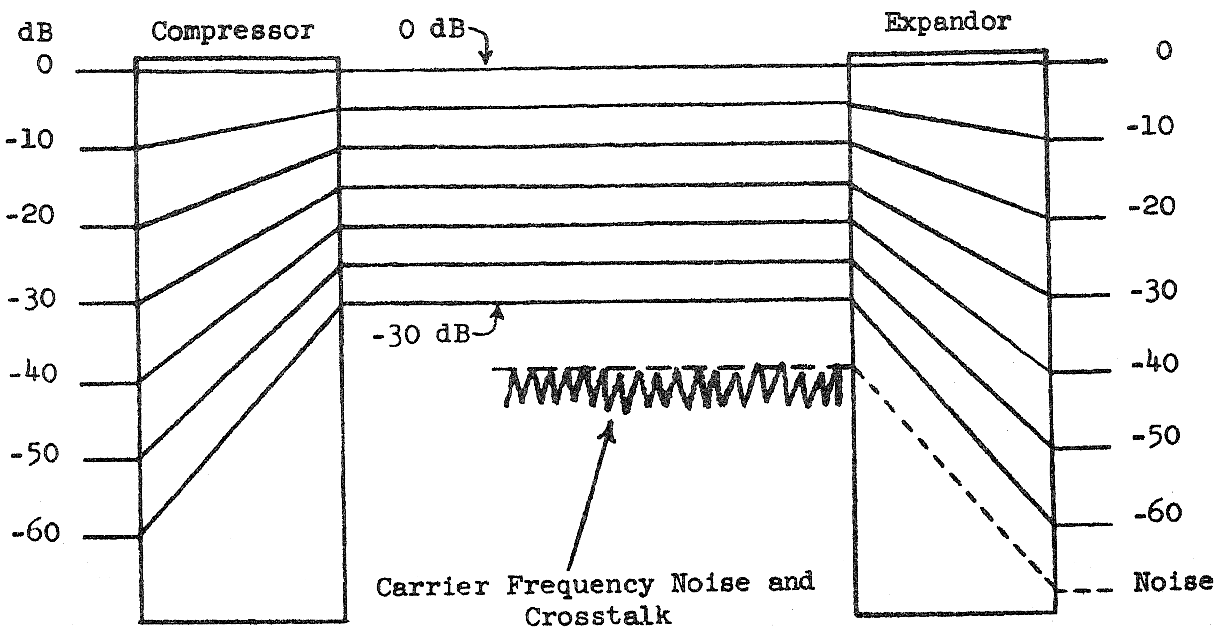


FIGURE 9

RINGING



A compandor is composed of a compressor on the sending end and an expandor on the receiving end. This compression of voice energy and expansion of voice <u>and</u> interfering noise and crosstalk gives an effective noise and crosstalk advantage.

Most compandors operate at a syllabic rate; this is, they change as a function of the energy contained in speech syllables and do not operate on extremely short (instantaneous) peaks of interference.

FIGURE 10

EXAMPLE OF COMPANDOR ACTION